

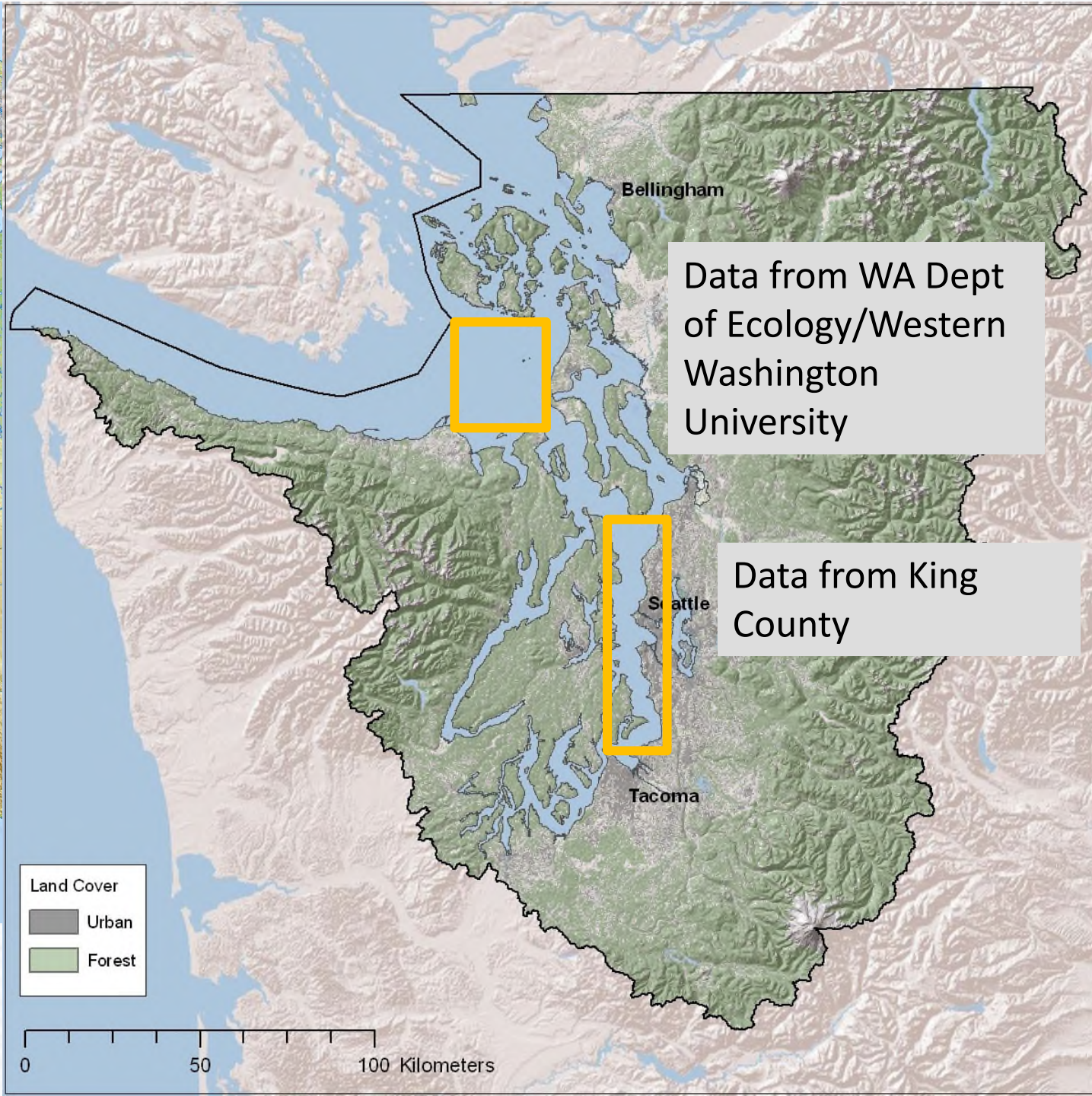
**Multiple indicators to assess for
potential marine water quality
impairments from nutrients in Central
Puget Sound, Washington**

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What makes Puget Sound unique?

- 2nd largest estuary in the US, one of most productive in the world
- Deep, glacial fjord average depth 62.5m, max ~280m:
 - Chesapeake Bay average depth 6.4m
 - San Francisco Bay average 7.6 m, max 30.5m
- Large tidal exchange: 3-4m
- Distinct basins and sills
- Ocean-dominated salinity: Puget Sound 83% seawater vs 50% seawater for Chesapeake Bay

Source: Puget Sound 2015 Fact book, Puget Sound Institute



How Do We Monitor Water Quality?



- **Offshore waters: 1994**
 - *CTD Sensors & Discrete Data*
- **Beach waters: 1999**
 - *Discrete Data*
- **Moorings: 2008**
 - *Automated sensors sample every 15-min*
- **Phytoplankton: 2008**
 - *Semi-Quantitative and FlowCam since 2014*
- **Zooplankton: 2014**
- **Sediments (offshore and beach)**



What are some potential impacts of human nutrient enrichment?

Nutrients

- ↑ Increased levels of nitrogen and phosphorus
AND
- ↓ Decrease in Silica:Nitrogen ratio

Phytoplankton

- ↑ Increased biomass, harmful algal blooms

Seasonality

- ≠ Longer growth and more persistent

Species richness

- ↓ May decrease and change

Species composition



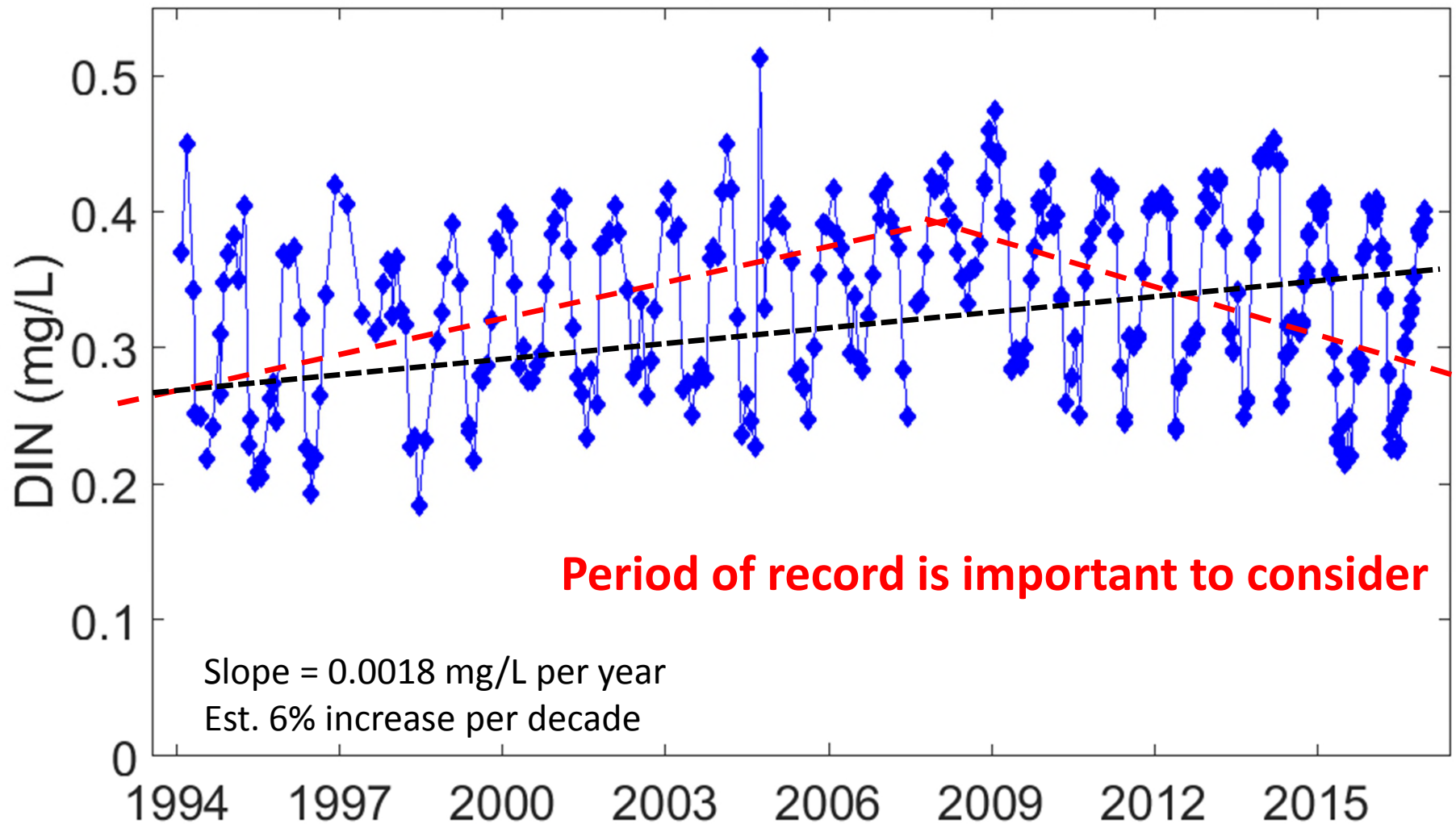
Dissolved oxygen (DO)

- ↓ Lower levels related to blooms
 - Decreasing trend in DO
- ↑
 - Increasing spatial extent of low DO

How can we quantify change with high seasonal variability?

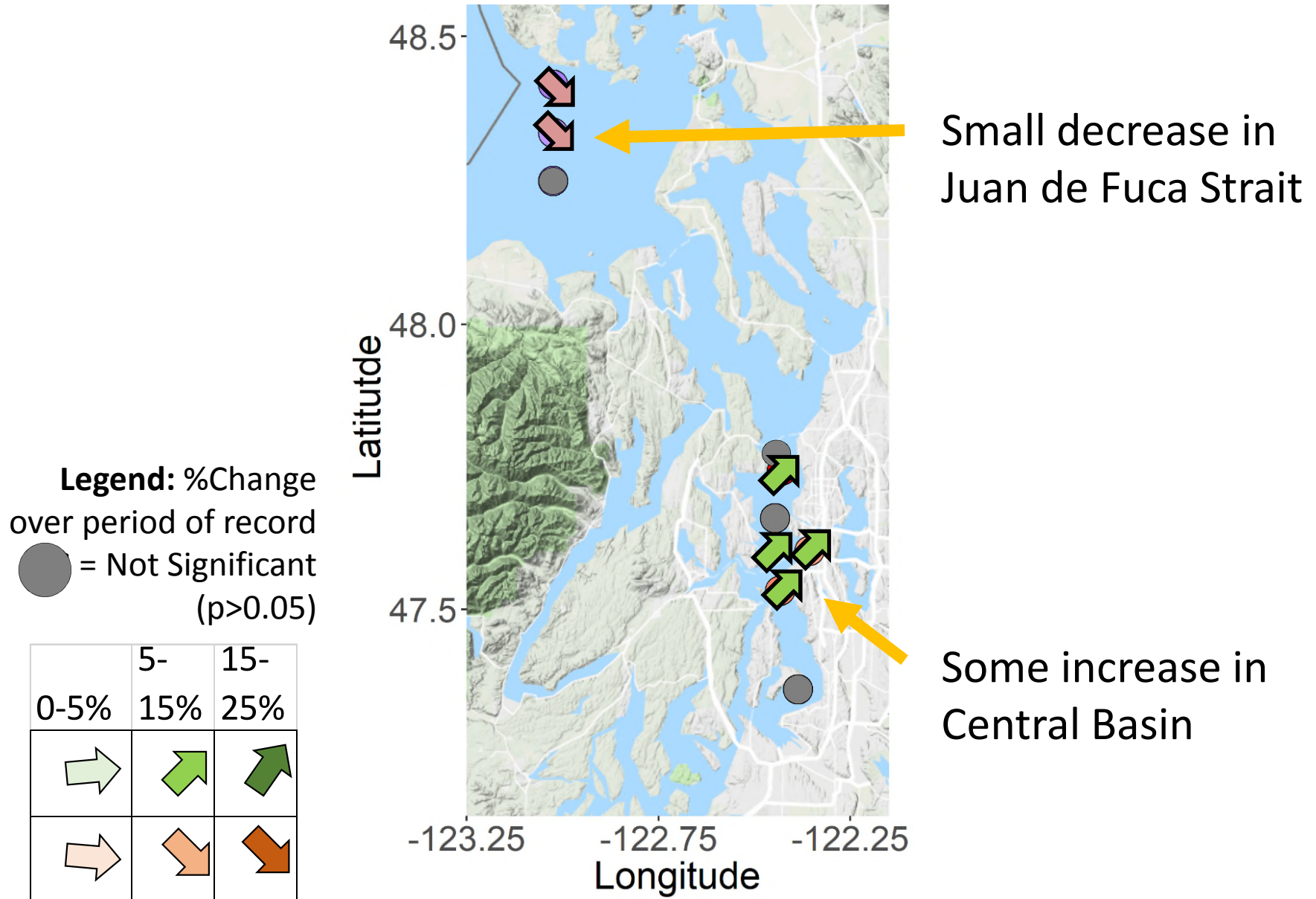
- One method = Non-parametric monotonic trend test by month (seasonal Mann-Kendall)

Point Jefferson – Significant trend at deep depth (200-m) (p-value < 0.05)



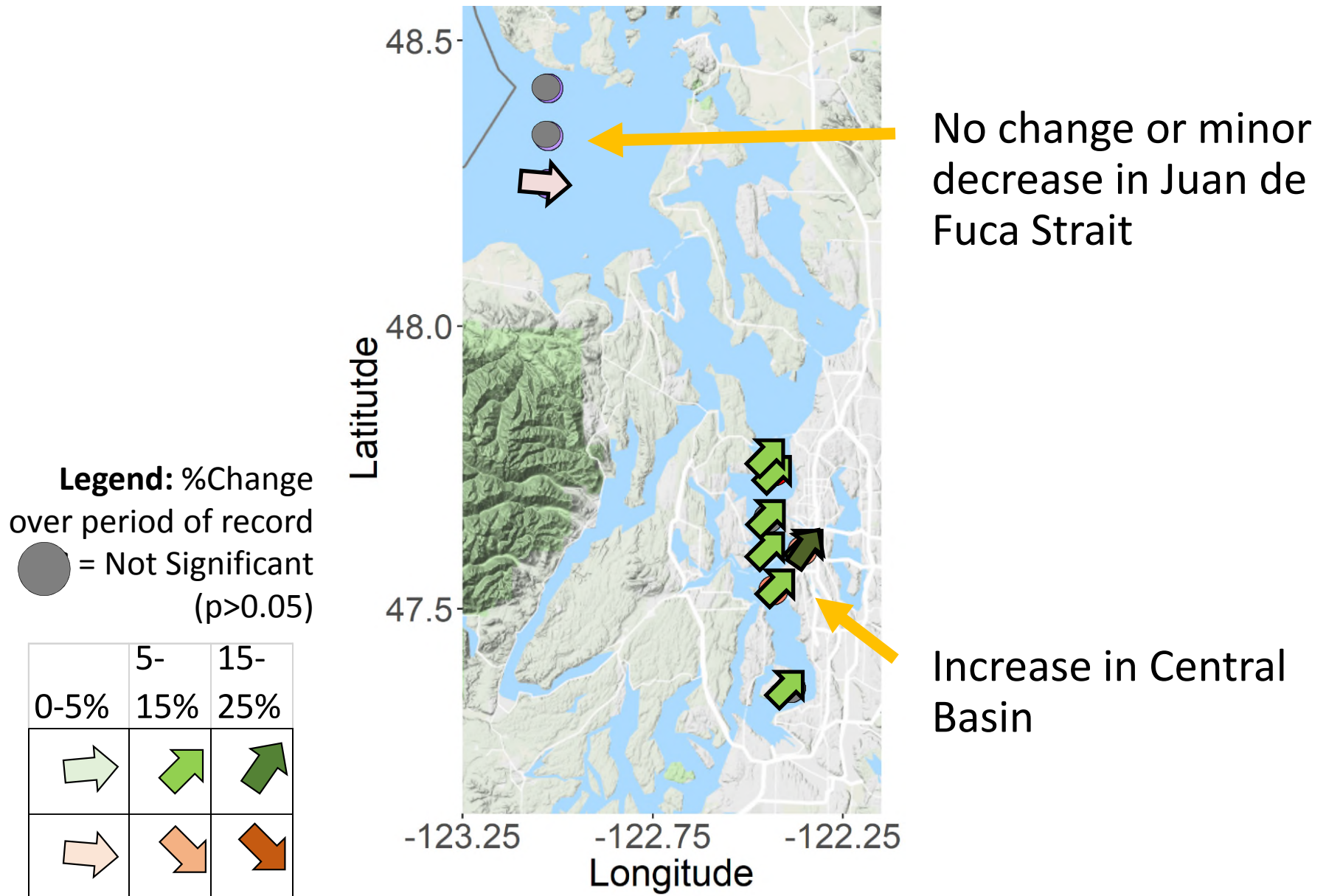
Trends over two decades

Dissolved Inorganic Nitrogen (DIN): 0-35m



Trends over two decades

Silica:DIN molar ratio: 0-35m





Fraser River freshet meets saltwater







(Source: A. Perea)

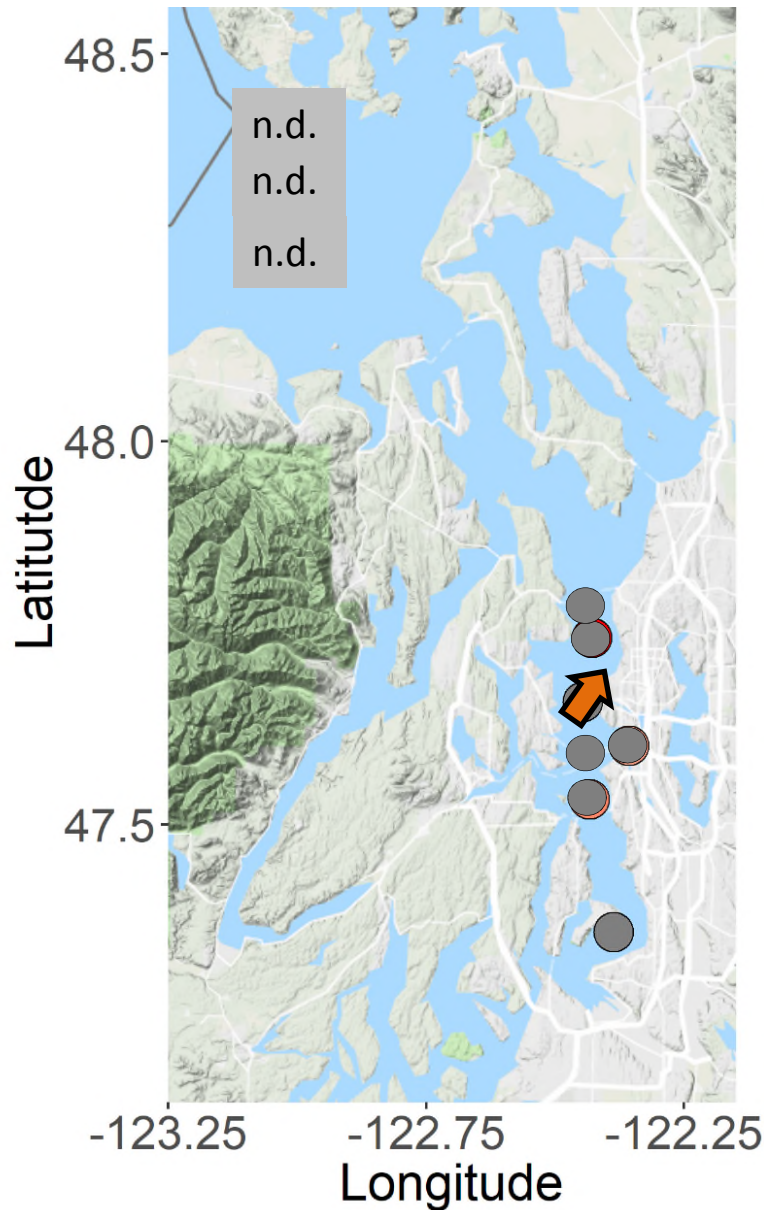
Potential
Drivers
??

Trends over two decades

Chlorophyll-a: 0m

Legend: %Change
over period of record
● = Not Significant
($p > 0.05$)

	5-	15-
0-5%	15%	25%
		
		







Generally low
concentrations
overall in Juan de
Fuca Strait

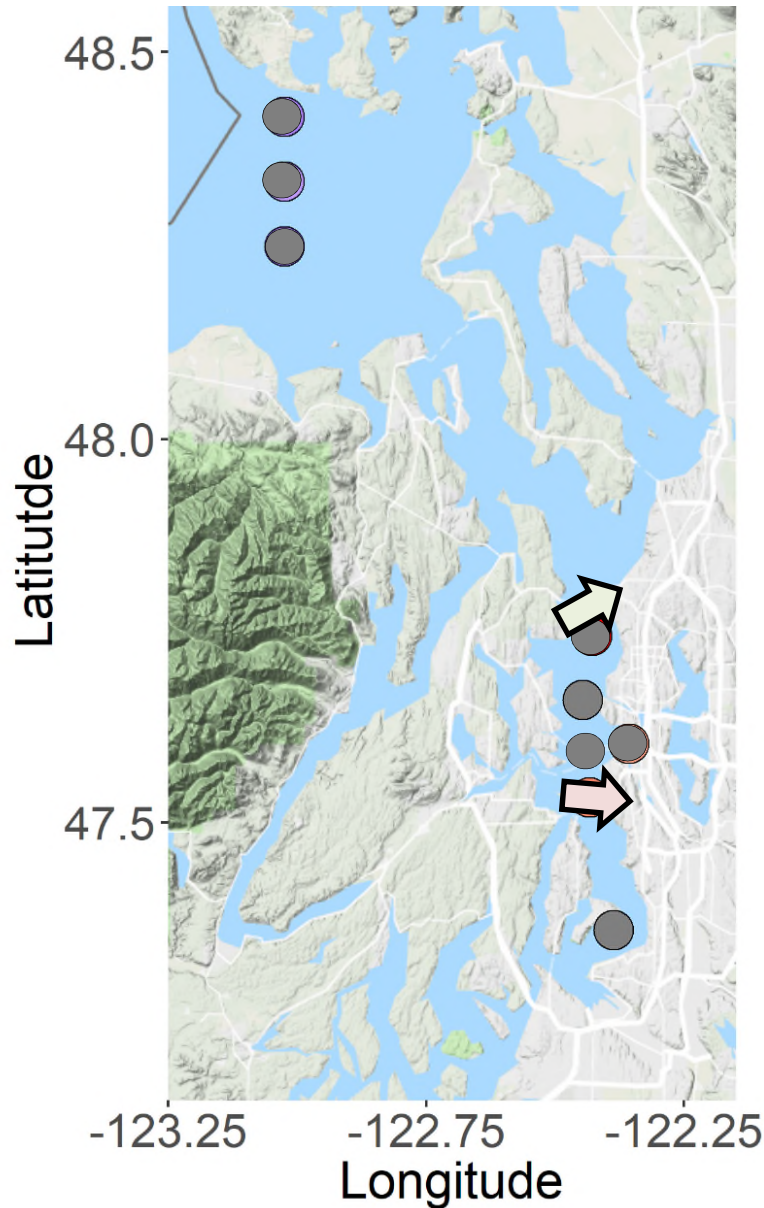
No clear changes in
Central Basin

Trends over two decades

Dissolved Oxygen (DO): Deep (55-200m)

Legend: %Change
over period of record
● = Not Significant
($p > 0.05$)

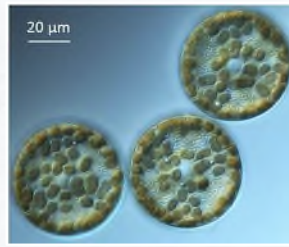
	5- 15%	15- 25%
0-5%		
		



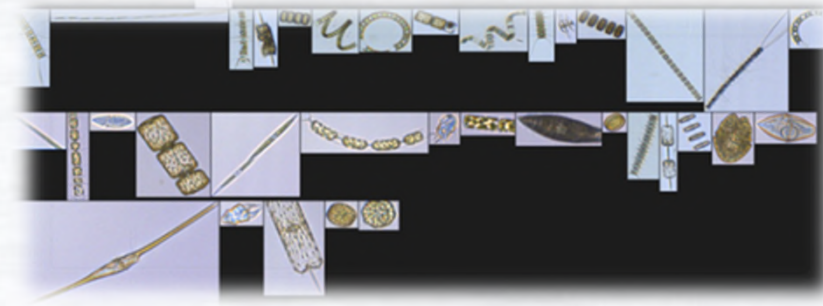
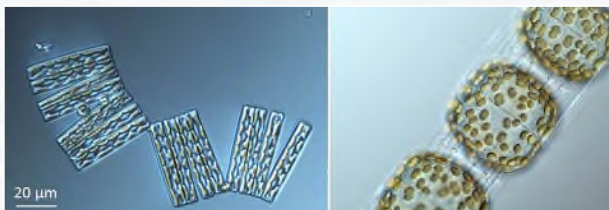
Generally low
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No clear changes in
DO

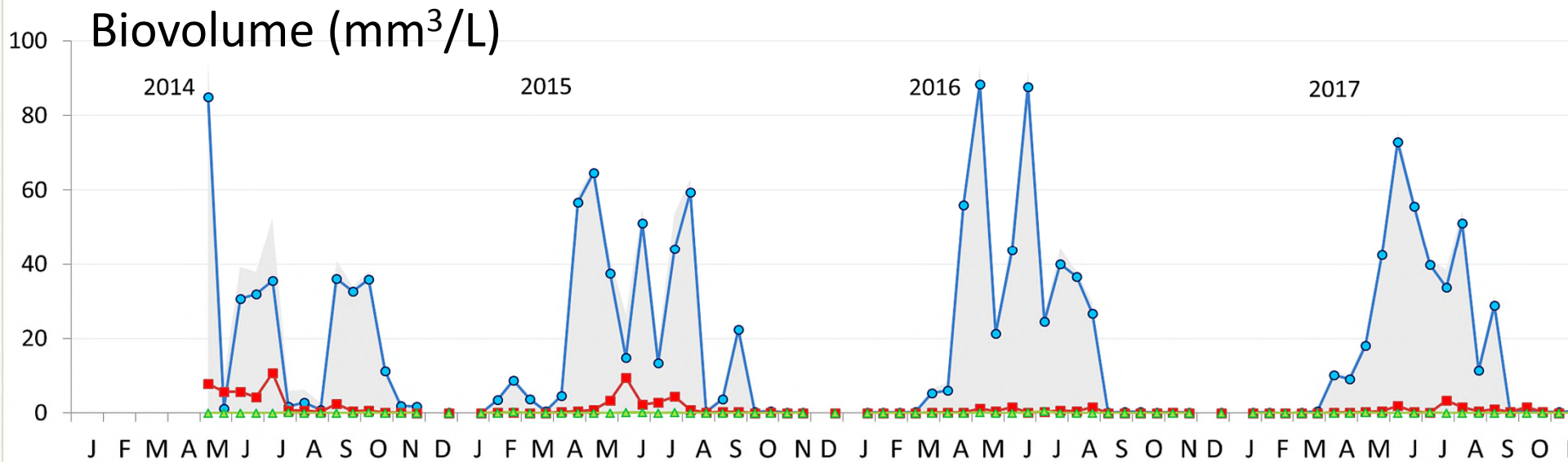
Phytoplankton – Key Points



- Puget Sound phytoplankton is dominated by diatoms
- Seasonal patterns in phytoplankton biomass vary year to year with environmental conditions
- Inter-annual variability in bloom timing, magnitude and species composition make it difficult to assess trends
- 10-yr record of Central Basin taxa shows a large group of common taxa present every year

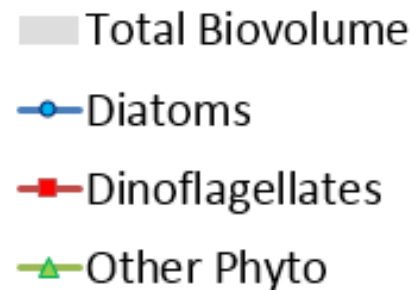


Puget Sound Central Basin: Seasonality of major taxonomic phytoplankton groups



Biovolume means of 6 stations (imaging technology)

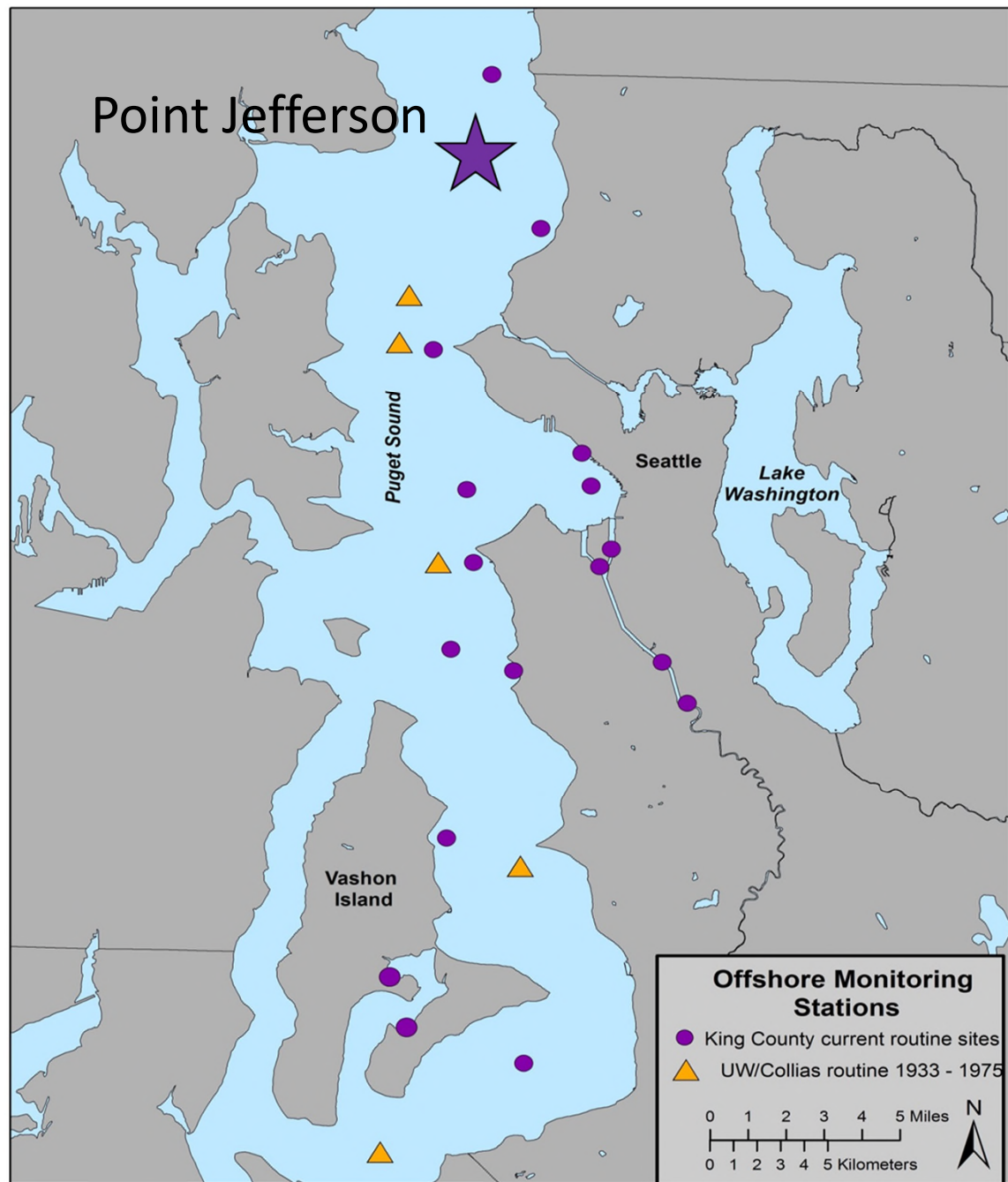
- Year to year variations in seasonal pattern
- Over 100 taxa identified over last 10 years (~60% diatoms, ~32% dinos, 8% other)



How does this
compare to
historical data
collected from
1933 – 1975?



Eugene E. Collias (1926- 2017)
(Source: Eugene and Dorothy
Collias Collection)



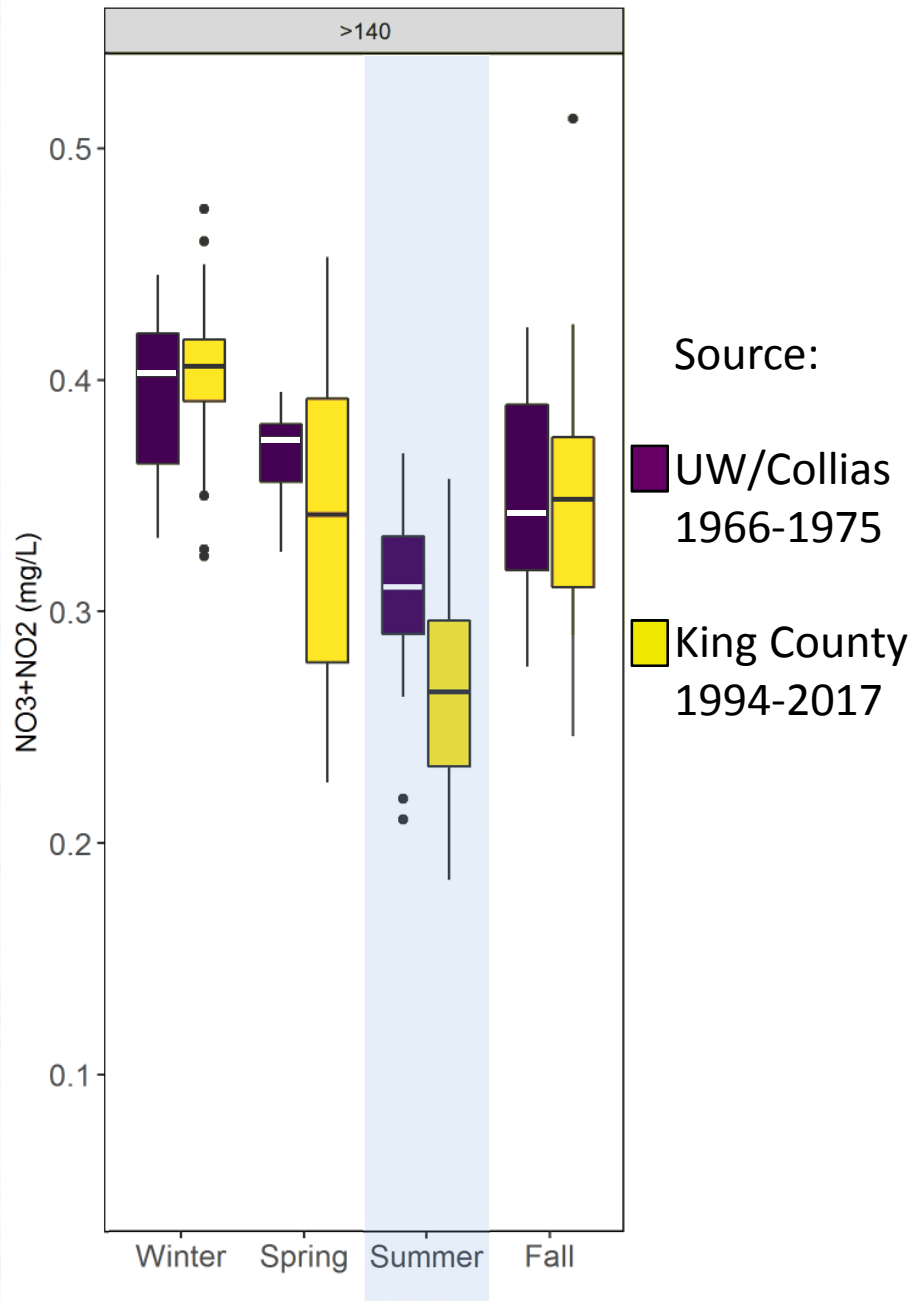
Historical Data Comparison – Key Points

- Limited for nutrients, especially nitrate, but...
 - Comparable nutrient levels to last century
- Clear monthly mean temperature increase of 0.5 – 1 °C in deep waters
- No clear changes in salinity or DO compared to Collias data (much longer records than nutrients)

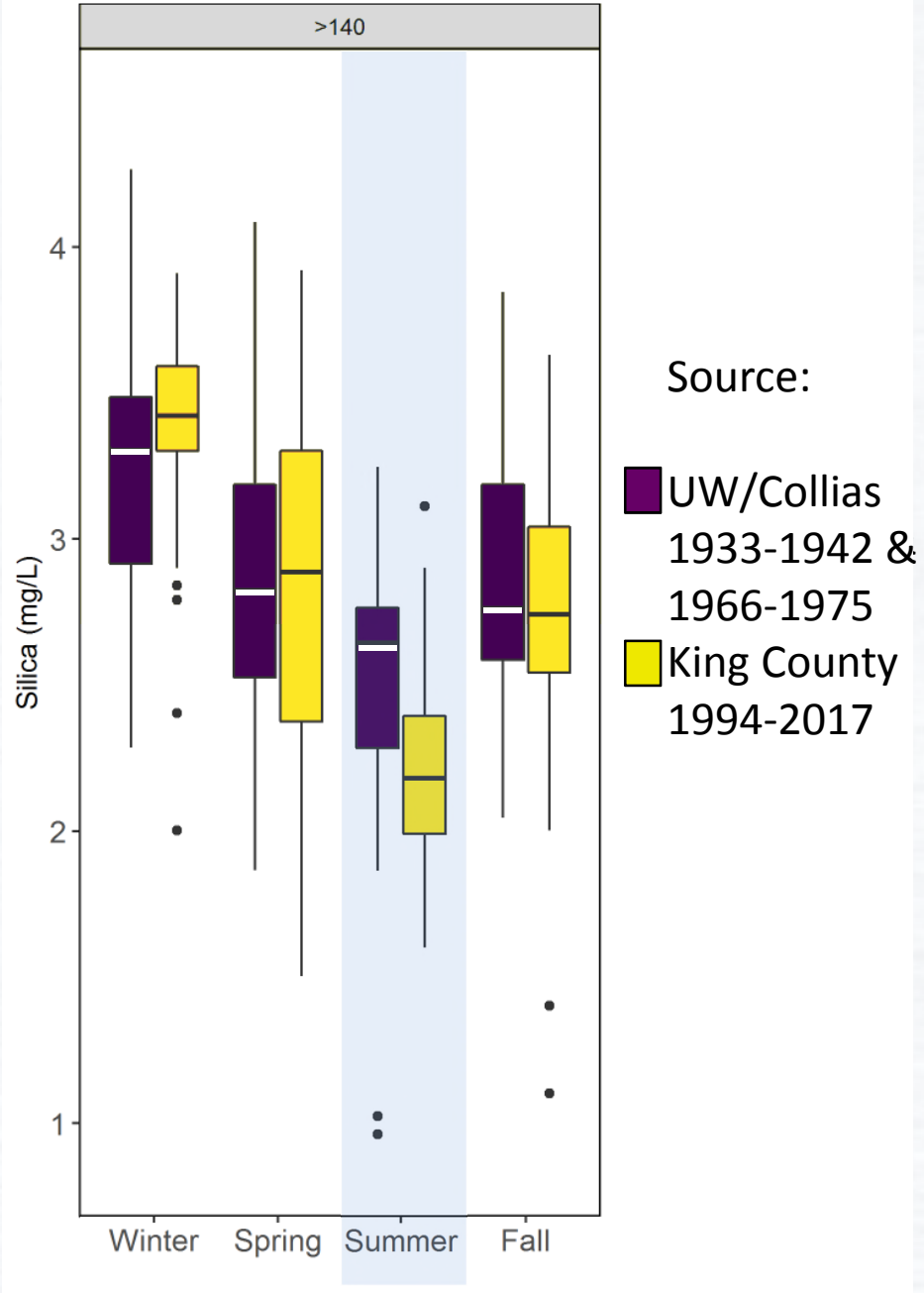
*R/V Brown Bear
(Source: Eugene and
Dorothy Collias
Collection)*



Deep Nitrate at Point Jefferson



Deep Silica



What do we observe in Central Puget Sound?

Nutrients



Increased levels of nitrogen and phosphorus

Investigate ocean/watershed balance



~~Decrease~~ in Silica:Nitrogen ratio

Phytoplankton

Seasonality

Species richness

Species composition



~~Increased~~ biomass

longer growth and more persistent

More data!

May decrease and change



Dissolved oxygen (DO)



Lower levels related to blooms

- ~~Decreasing~~ trend in DO

- Increasing spatial extent of low DO



Considerations and Limitations

- Place matters
 - Physical conditions impact susceptibility to eutrophication
 - Must evaluate impairment indicators beyond nutrient concentrations
 - Nutrient impacts can be far-field
- Variability is the back drop to assessing change
- Consistent long-term monitoring is key
- Information gaps in understanding of a complex ecosystem
 - A tool box of multiple indicators can come in handy
- Increasing temperatures and other climate change impacts must be considered



Thank you!

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<http://green2.kingcounty.gov/marine>

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- King County Environmental Lab staff for field sampling and lab analysis

